TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 217

CONTROL OPERATING MECHANISMS FOR AIRPLANES.

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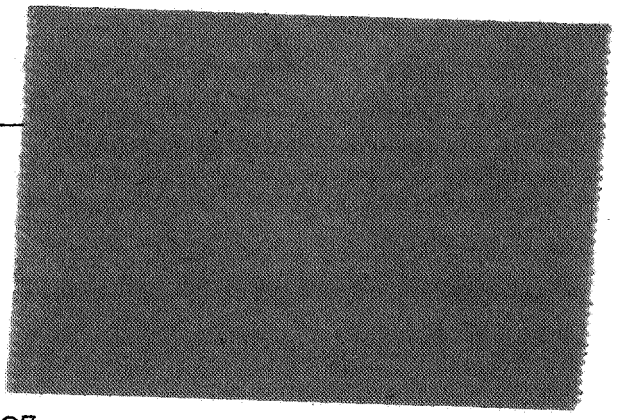

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The elevators, rudder, and ailerons of an airplane are supposed to be instantly movable at the pilot's will. The mechanical system which is used to actuate them must be such that there will be no lost time and no lost motion. When the pilot operates his control he wants to know just what the effect will be and just when it will occur.

The connections between the cockpit and the control surfaces are, as a rule, remarkably simple. In most instances, in fact, they consist simply of wires, arranged in pairs, so that the controlling force, whatever its direction may be, is transmitted through the wire by a pull, never by a push. Wires are capable of taking force in one direction only.

When the connections have been followed to the cockpit, the pilot's controls, also, are found to be strikingly uniform in type. The vast majority of all airplanes built at the present time are fitted with stick controls, consisting of a stick rising vertically from the floor of the cockpit and foot-bar. The stick is moved fore and aft to control the motions of the elevator, a backward movement pulling the rear edge of the elevator up and so causing the airplane to climb. A transverse motion of the same stick governs the ailerons. When it is pushed towards the left the rear

*Taken from Christian Science Monitor.

edge of the left aileron is pulled up while the right aileron is pulled down. The lift of the right wing is then increased at the expense of that of the left, and the right wing is raised while the left is depressed. The operation of these two controls is of course quite natural, as the veriest novice, quite without knowledge of the piloting of an airplane, instinctively leans towards the high side when the airplane tilts. Leaning towards the high side and dragging the stick with him, he is operating the control in the proper manner for the restoration of equilibrium.

The rudder is controlled through the foot-bar, which bears a superficial resemblance in form and function to the handle-bar of a bicycle. There is little real similarity, however, as the operation is exactly opposite from that of a handle-bar. The pilot must push his right foot forward if he wishes to make a turn to the right. This motion, also, quickly becomes instinctive.

For and Against the Stick.

The stick control, as just described, certainly represents the ultimate in simplicity. It is hardly possible to think of any means whereby three distinct controls can be operated with a device containing so few parts. There have been few occasions when the stick seemed likely to have any rival in general favor.

There are only three objections to the stick. In the first place, it is not satisfactory for very large airplanes because it gives insufficient controlling power. Second, its operation in an airplane insufficiently stable to be left to itself requires the

use of both feet and one hand and gives the pilot little opportunity to attend to machine guns or any other equipment. Finally, the patent situation is rather involved, as the French inventor of the stick control has lately been suing all other airplane manufacturers for fabulous sums for royalties in virtue of airplanes built during the war and using his device.

The Problem of the Giant.

The problem of the control of the giant airplane is a serious one, and should be discussed at length as a separate topic. If manually-operated controls of the present type are to continue to be used, increasing size of the surfaces to be moved requires either that the pilot should exert an increased force on his control or that the gear ratio should be changed so that the stick, wheel, or whatever other device may be used will be moved through a larger distance for a given ultimate effect. If two airplanes are alike except in that it requires a six-inch movement of the upper end of the stick to pull the trailing edge of the elevator up three inches on one, while the control connections are changed on the other so that a three-inch movement suffices for the same purpose, the force applied to the stick by the pilot's hand in order to produce a given effect will be twice as great in the second case as in the first.

The reduction of force on the stick by gearing down is limited by the pilot's reach and by the dimensions of the cockpit. The total movement of the stick cannot, in any instance, much exceed 24 inches, and this must correspond to the full desired range of

angular movement of the control surfaces.. So far as the ailerons, at least, are concerned, however, the limitation can be overcome by the substitution of wheel for stick control. If the control column is capped by a wheel, which is rotated to operate the ailerons, the gearing can be reduced to anything desired, as the wheel can be turned through several full turns for the extreme range of aileron movement just as the wheel on a sailing vessel or small steamer is often turned through several revolutions to move the rudder to its full extent. Unfortunately, there is no apparent means of doing for the elevator control what the wheel on top of the column does for the ailerons in increasing the ease of movement.

Efforts to Find a Substitute.

The efforts so far made to overcome the second suggested objection to stick control have in most cases been more bizarre than practically useful. It is of course, possible, at least in theory, to combine three distinct operations on a single control member, but the difficulty of moving that member in such a way as to secure exactly the effect desired, combining the movements of the various control surfaces in just the proper proportion, is certain to be very great. The training of pilots for a "three-in-one" control would be a much longer process than their training for the present simple type. Nevertheless, a number of such controls have been designed and tried, combining two direct movements with one rotation. A column surrounded by a wheel, for example, can be moved fore and aft or sideways exactly like the stick, and the wheel can

be rotated to give a third control. To rotate the wheel without moving the column at all would obviously require great care and the constant use of both hands. At least one control has been designed, also, to be operated with the feet alone, leaving the hands entirely free.

The third objection to the stick was found in the patent situation. Fortunately for the American industry, that trouble seems likely to be confined to France, or at most to Europe. In France the inventor of the stick control, whose patents date back more than 15 years and who was one of the pioneer pilots and constructors, has received a judgment for several million francs in royalties. However, we may welcome the spectacle of an individual inventor getting his full dues in monetary form, the burden of such a payment is one which the aeronautical industry at the present time, when the recovery from the post-war collapse is not yet complete, is ill able to bear.

Mechanically Operated Gear.

So far as manually-operated controls are concerned, then, the stick for small airplanes and the wheel and column for large ones appear to give the answer. A point will ultimately be reached, however, at which manually-operated controls will not suffice, and a mechanically or electrically operated gear will have to be used, just as a steam steering gear is always used on large ships. The stick will then have no function except to open and close air valves

or to operate switches and rheostats for controlling the flow of electricity, and the pilot will not have to exert any force at all. That prospect is not altogether an attractive one, as a pilot judges the behavior of his airplane to some extent by the feel of his control, as the helmsman of a small boat gages its operation in part by the feel of the tiller. With no force on the stick, that feel would be lost, and the pilot would have to change his methods of flying, depending on instruments more than is now common. The ideal arrangement, from the point of view of the pilot, would be found in the provision of a mechanical device which always did nine-tenths of the work of controlling, leaving the other tenth to the pilot himself in order that he might be warned, by the seeming slackness of the control and the poor response of the airplane, when he was getting into an attitude dangerously near that of stalling.